PB83-246132

Respiratory Effects on Population from Low-Level Exposures to Ozone

Arizona Univ. Health Sciences Center, Tucson

Prepared for

Health Effects Research Lab.
Research Triangle Park, NC

1983

U.S. Department of Commerce
National Technical Information Service
NTIS

PB83-246132

EPA-600/D-83-108
August 1983

RESPIRATORY EFFECTS ON POPULATIONS FROM LOW-LEVEL EXPOSURES TO OZONE

By

Michael D. Lebowitz, Ph.D.
Professor of Internal Medicine
C. J. Holberg, M.S.
R.R. Dodge, M.D.

Division of Respiratory Sciences
University of Arizona Health Sciences Center*
Tucson, Arizona 85724

EPA Project Officer
Carl Hayes

This work was supported by EPA Grant #R805318010 and NHLBI SCOR Grant #HL14136.

HEALTH EFFECTS RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

*Equal Employment Opportunity/Affirmative Action Employer

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-600/D-83-108		

4. TITLE AND SUBTITLE	5. REPORT DATE
Respiratory Effects on Populations from Low-Level Exposures to Ozone	1983
	6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
M.D. Lebowitz, C.J. Holberg, R.R. Dodge	

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Division of Respiratory Sciences University of Arizona Health Sciences Center Tucson, AZ	AAGATD
	11. CONTRACT/GRANT NO.
	R805318

12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Health Effects Research Laboratory Office of Research and Development U.S. Environmental Protection Agency Research Triangle Park, NC 27711	14. SPONSORING AGENCY CODE EPA-600/11

15. SUPPLEMENTARY NOTES

P.O. Carl Hayes

16. ABSTRACT

A symptom stratified, geographic cluster sample of 117 middleclass households (211 subjects) was studied in Tucson, AZ. Daily symptom diaries and peak flows were obtained Included were 24 white children age 5 to 25 (middleclass) with total person days of 1512 and adults by chronic symptom group. $\dot{V}$max was sex, age, height and season corrected. Children's $\dot{V}$max were within normal range; adult $\dot{V}$max was correlated with chronic symptom and smoking. Ambient O_3, NO_2, CO, TSP, temperature (T) and relative humidity (RH) were monitored. Indoor sampling was performed in 41 houses was for O_3, TSP, RSP, CO, T, RH. Type of stove and smokers in households were determined. Analysis of variance was controlled for season, CO, NO_2, TSP, and indoor pollutants. O_3, TSP and T were significantly correlated with children's $\dot{V}$max. Children's $\dot{V}$max for person days with maximum hourly O_3 0.08 - 0.12 represented a 10.3% decrease (p .007); it represented a 14.8% decrease for mean O_3 (between 3-7 pm) 0.08 ppm (p .0001). Normal adults' $\dot{V}$max was correlated with O_3 also.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field Group

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
Release to Public	Unclassified	10
	20. SECURITY CLASS (This page)	22. PRICE
	Unclassified	

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

INTRODUCTION

A major difficulty in studies of the acute effects of ozone on morbidity has been the interference of potential interaction between ozone and other pollutants and temperature. Studies of exacerbations of asthma and other airway obstructive diseases have suffered from the lack of medication information, missing data and analytical problems with concurrent attacks. Studies which have been able to evaluate asthmatic attacks, while controlling some co-linear and confounding variables, have shown consistent effects of ozone. Several studies have shown ozone exposures with respiratory irritant effects even after controlling for other pollutants and temperature (NRC, 1977; EPA, 1978; Ferris, 1978; Bates, 1979).

Studies on acute effects of pulmonary function in children (Kagawa et al., 1975, 1976; Wayne et al., 1967; Lebowitz et al., 1974; Fabbri et al., 1979; Lippmann, 1982) indicate a consistent findings that as ozone increases, peak flow and spirometric flow volume measures are decreased, in a fairly linear fashion over the range of values studied (0.01 - 0.15 - 0.30 ppm), even after controlling for temperature and other pollutants. These results are consistent with controlled human exposure studies (EPA, 1978). There are several major factors that appear important for the effect of O_3 on pulmonary function: one is exercise and the other is the contribution of other pollutants and temperature.

This paper will attempt to evaluate the respiratory effects of ozone, independently and interdependently of other pollutants and meteorological phenomena, both indoors and outdoors.

The study was conducted in a representative community population sample in Tucson, AZ Previous studies in this population sample indicated the presence of relationships between weekly symptoms and both air pollutants and allergens, controlling for weather (Lebowitz, 1977).

METHODS

A total of 117 families (229 subjects) were derived from a stratified sample of families in geographic clusters from the community population under study (Lebowitz et al., 1975).
The families studied were representative of families, with and without reported asthma, in their clusters. They were monitored over a two-year period, using daily symptom diaries and mini-Wright peak flow meters (Lebowitz, et al., 1982). Daily response rates were acceptable for a majority of days in all seasons. The subjects were trained in the use of the diaries by trained nurses (as per Lebowitz et al., 1975). Monthly checks by phone and seasonal checks by visit were made to insure proper usage and to calibrate peak flow meters. All families provided environmental information on their houses, heating, cooling, type of appliances, and smoking in the household.

Indoor and micro-outdoor monitoring was conducted in a random cluster sample of study households (n=41) for air pollutants, pollen bacilli, fungi, and algae, for 72 hours each. Macro-monitoring for pollen and TSP (hi-vol.) was conducted simultaneously in the center of each cluster. Indoor samples were measured in living rooms and kitchens. Particles were measured using Gelman filters attached to a Thomas pump (1.7 L/m) for totals (TSP) and with a cyclone fractionator for respirables (RSP); identical units were used outside the house (one in front and one in back). O_3 was measured using a Daisibi (UV photometer) monitor. CO was measured using grab bag samples and a Bendix CO IR analyzer. NO_x measurements using Bendix chemiluminescent analyzers from EPA were unsuccessful. Pollen, algae and fungi were collected as previously reported (Lebowitz et al., 1982). Daily macro-monitoring of air pollutants was performed routinely by the Pima County Health Department and daily weather data were provided by the U.S. Weather Bureau for various sites. Ozone was monitored outdoors by the chemiluminescent method at three stations; previous inventories by the Pima County Air Quality Control District showed significant homogeneity of O_3 in the basin (AQCD, 1978). Average regional values were therefore used for analysis of all clusters, and closest-station values for individual clusters. Comparisons showed no significant changes in results when using regional averages or closest daily hourly maximum values. Symptom rates per 100 person days were calculated from daily diary data for asthmatics and non-asthmatics within exposure groups, for comparative purposes.

There were 24 children from middle-class backgrounds studied for an 11 month period in 1979-1980. After age and height correction, no peak flow differences in baseline data were seen between the children, all were within the normal range. Each child's daily peak flow was converted into a season-specific standard normal deviate (Z-score), utilizing their seasonal mean and standard deviation.

There were 23 adult asthmatics in one cluster, and a total of 35 adult asthmatics, with daily peak flows; there were 353 days with sufficient information (>5 individuals/day). There were an additional 544 days with sufficient information (n>5) from adults with reported chronic symptoms of airway obstructive diseases (AOD), 494 days from adults with reported allergies, 312 days from asymptomatic adults. For adults, Z- score transformation of peak flows used sex-age-height-season specific values. Thus, all peak flows ($\dot{V}max$) were adjusted for co-variables and were in the same relative units (with $\bar{x} = 0$, $s = 1$). When individuals were the unit of study, a person-days dummy variable was used in analysis to eliminate effects of the different number of individual person-days of observation.

Statistical analysis used SPSS programs on a DEC 10-Cyber 175 computer system. Unless otherwise noted, statistical significance refer to a $p<0.05$. Multivariate analyses of variance and regression methods were utilized to examine interactions and control for co-linear variables.

RESULTS

Exposures:

Total suspended particulate (TSP) indoors ranged from 5.7 to 68.5 $\mu g/m^3$. Simultaneous micro-outdoor TSP ranged from 2.1 to 169.6 $\mu g/m^3$. Cyclone measurements of respiratory particulate (RSP), were often below readable levels; the maximum was 49.7 $\mu g/m^3$ indoors and 124.5 $\mu g/m^3$ outdoors. Scanning electron microscopy yielded little identifying information on the type of dust found on the floors of homes. Total micro-outdoor pollen counts were approximately 5% of the macro-pollen counts (max = 1517), and micro-indoor pollen counts were only 5% of the micro-outdoor pollen counts. Floor samples contained high counts of nonsuspended pollen in the spring, as determined by light microscopy; the amount found was insufficient to show up on the SEM. The common pollen in this region usually had Gaussian distributions of mass median aerodynamic diameter (MMAD), ranging from 17 to 36 µm. The minimum MMAD were generally between 10 and 15 µm.

(Algae found outside or in evaporative coolers were not found indoors. Fungi were either ubiquitous or only found in one location (indoors, outdoors, or in coolers). Aspergillus found indoors does not appear to produce skin tests reactivity.)

Indoor TSP was significantly correlated with micro-outdoor TSP ($r=.71$, $p<.001$) and cluster TSP ($r=.4$, $p<.05$); the latter ranged from 27.5 - 129 $\mu g/m^3$ on days of indoor monitoring. Indoor RSP was significantly correlated with micro-outdoor RSP ($r=.77$, $p<.001$). Indoor micro-outdoor TSP and RSP were higher when all outside streets around the house were dirt (rather than paved, but not when only the "back alley" was unpaved. However, as previously mentioned, indoor TSP and RSP had different chemical and physical characteristics than outdoor TSP and RSP. Measurements showed about a 10-fold fall of outdoor TSP within 5 feet of the front door and about a 100-200-fold fall of outdoor TSP in the middle of the living room. Both TSP and RSP were significantly associated with environmental tobacco smoke, but not with gas stove usage. Indoor TSP and RSP showed no temporal trends indoors, although regional TSP has a daily trend.

Neither environmental tobacco smoke nor gas stove usage was associated with social status in this sample. Attempts to estimate concentrations of CO, TSP, and RSP in houses not monitored, by cluster and season, essentially yielded a classification based on gas stove usage and smoking in the houses.

O_3 and TSP were significantly negatively correlated with children's peak flow and season was significantly correlated with children's $\dot{V}max$ as well. CO and NO^2 were not significantly correlated with $\dot{V}max$. Multifactor analysis of variance was conducted to control for season, CO, NO_2, and total suspended particulate, after which the ozone was

still shown to be significant at $p<0.001$. The interaction between ozone and TSP in relation to peak flows was statistically significant (Table 1). Using the mean hourly O_3 readings between 3-7 pm yielded the following:

O_3 (ppm)	Mean $\dot{V}$max	Person-days
< 0.038	+.1254	157
.038 - .051	+.1207	86
.052 - .079	-.2313	81
.08 - .12	-.3760*	7

* Represents a greater than 14% decrease from baseline.

A multivariate analysis of variance was performed with the children's $\dot{V}$max to look for other possible meteorological covariates and indoor pollutant effects as well as O_3 and TSP. High relative humidity ($p<.001$) or precipitation ($p<.025$) were independently related to $\dot{V}$max as was gas stove use ($p<.005$, not by itself but only after all other factors and interactions were adjusted). TSP and O_3 still had the same effects on $\dot{V}$max (as shown in Table 1). The independent effect of O_3 was predominantly in children from homes without smokers, although there was no effect of passive smoking per se, and the mean $\dot{V}$max Z-score was -0.48 in these children for days of $O_3 \geq 0.08$ (84 person days), representing an approximately 18% decrease from baseline $\dot{V}$max. Also, temperature and O_3 interacted significantly in relation to $\dot{V}$max.

After adjusting $\dot{V}$max for person days, TSP, temperature and stove use, using multiple regression analysis, O_3 was still significantly correlated with $\dot{V}$max ($p = .013$) and the multiple R was 0.23 ($p<.001$). The regression of predicted $\dot{V}$max on O_3 was linear with an $r = -0.06$ ($p<.001$; n=674 person days), with predicted $\dot{V}$max = $0.287 - 6.025 \times O_3$ (intercept statistically significant also). The regression of residual $\dot{V}$max on O_3 was significant with an $r = 0.070$ ($p<.035$, resid. $\dot{V}$max = $0.17 - 3.20\ O_3$; intercept also statistically significant). After removing TSP (smaller n) and adjusting $\dot{V}$max for relative humidity as well, O_3 and predicted $\dot{V}$max had an $r = -0.56$ ($p<.0001$, n=1513 person days) (predicted $\dot{V}$max = $0.17 - 3.87\ O_3$), and residual $\dot{V}$max plotted against O_3 had an $r = -0.076$ ($p<.002$; resid. $\dot{V}$max = $0.20 - 3.71\ O_3$). Gas stove use was borderline significant ($p=.066$) in the first regression, but not significant ($p<.25$) in the second.

In adults, smoking had the biggest effect on $\dot{V}$max. In adults with AOD symptoms, O_3 was significantly related to $\dot{V}$max ($p<.002$) after adjusting for smoking and relative humidity as covariables, TSP and gas stove usage as other main effects; TSP was also significant ($p<.01$) and the O_3 - TSP interaction had a $p = .104$ ($n = 258$ days). Using the same

variables in multiple regression yielded a regression coefficient of -5.946 for O_3 ($p<.005$ by t test); the regression coefficient for TSP was + 0.004 ($p<.0025$). In 23 asthmatics in one geographic cluster where indoor monitoring was most complete, O_3 and temperature had a significant interaction in relation to $\dot{V}max$; O_3 had an association with $\dot{V}max$ only in low temperatures. However, O_3 was not independently significantly related to $\dot{V}max$ after adjusting for outside CO, temperature, humidity, age, smoking, gas stove use, indoor TSP, and micro-pollen (fungi was not independently important). There was an interaction of O_3 and temperature with prevalence rates of acute "asthma" symptoms in these asthmatics as well, but O_3 had no independent effect within any temperature range. It had no effect on incidence rates of "asthma attacks" either. O_3 did have a significant association with prevalence rates of rhinitis in conjunction with stove usage ($p<.015$) in this group (using multivariate analysis of variance controlling for temperature). Its effect was seen only in those with gas stoves:

O_3	Rhinitis Prevalence rates*	Person days
<.032	39.3	49
.032 - .051	41.9	90
.052 - .12	44.8	67

* $p<.0001$ (ANOVA)

No other adults $\dot{V}max$ or symptoms were related to O_3 in other symptom groups.

DISCUSSION

As children in this study were found to spend more time outdoors and have more exercize, the findings of an outdoor O_3 association with $\dot{V}max$ is not surprising; it confirms our previous studies (Lebowitz et al., 1974). However, the O_3 level at which $\dot{V}max$ effects were seen, though consistent, is lower than expected. One can only surmise that the significant effect is occurring primarily ≤ 0.08 ppm, even after controlling for everything else measured in this study that was also significantly related to $\dot{V}max$. In the adult asthmatics, this effectively eliminated the association of $\dot{V}max$ and "attacks" with O_3, though they showed some relation of O_3 with rhinitis in those with gas stoves.

This study of children and of adult asthmatics, because of the small numbers of subjects, needs repeating to determine the consistency of the relationships found. Furthermore, personal monitors, if they were available, would provide more accurate exposure estimates; total exposure is unknown. Finally, it is not inconceivable that O_3 is acting as an index of some unknown factors which were not measured.

REFERENCES

1. National Research Council (NRC), Ozone and other photochemical oxidants. National Academy of Sciences, Washington, D.C., 1977.
2. U.S. Environmental Protection Agency, Air quality criteria for ozone and other photochemical oxidants. Research Triangle Park, NC: Environmental Criteria and Assessment Office; EPA report no. EPA-600/8-78-004, 1978.
3. Ferris, B.G., Jr., Health effects of exposure to low levels of regulated air pollutants: a critical review. J. Air Pollut. Control Assoc. 28(5):481-497, (1978).
4. Bates, D.V., Community air pollution in Canada. A review and predictions for the 1980's. Can Med. Assoc. 120:1252-1256, (1979).
5. Kagawa, J., Toyama, T., Photochemical air pollution: Its effects on respiratory function in elementary school children. Arch. Environ. Health 30:117-122, (1975).
6. Kagawa, J., Toyama, T., Nakaza, M., Pulmonary function test in children exposed to air pollution. In: Finkel A.J. and W.C. Duel, ed., Clinical implications of air pollution research. Acton, MA: Publishing Sciences Group, Inc., 1976, pp. 305-320.
7. Wayne, W.S., Wehrle, P.F., Carroll, R.E., Oxidant air pollution and athletic performance. J. Am. Med. Assoc. 199:901-904, (1967).
8. Lebowitz, M.D., Bendheim, P., Cristea, G., Markowtiz, D., Misiaszek, Jr., Staniec, M., Van Wyck, D., The effect of air pollution and weather on lung function in exercising children and adolescents. Am. Rev. Resir. Dis. 109:262-273, (1974).
9. Fabbri, L., Mapp, C., Rossi, A., Sarto, F., Trevisan, A., De Rosa, E., Pulmonary function changes due to low level occupational exposure to ozone. Med. Lav. 70(4):307-312, (1979).
10. Lippmann, M., Lioy, P.J., Leikauf, G., Green, K.B., Baxter, D., Morandi, M., Pasternack, B.S., Effects of ozone on the pulmonary function of children. Adv. in Mod. Environ. Tox. (1982).
11. Lebowitz, M.D.,Temporal analysis of acute respiratory symptoms, aero-allergens and air pollution. IEA Proc. 194, (1977a).
12. Lebowitz, M.D., Knudson, R.J., Burrows, B., The Tucson epidemiology study of chronic obstructive lung disease. I. Methodology and prevalence of disease. Am. J. Epidemiol. 102:137-152, (1975).
13. Lebowitz, M.D., O'Rourke, M.K., Dodge, R., Holberg, C.J., Corman, G., Hoshaw, R.W., Pinnas, J.L., Barbee, R.A., Sneller, M.R., The adverse health effects of biological aerosols, other aerosols, and indoor micro-climate on asthmatics and non-asthmatics. Environ. Int. 8:375-380, (1982).
14. Pima County Air Quality Control District (AQCD), The geographical distribution of ground-level ozone in metropolitan Tucson, AZ. Summer 1977, AQCD Monitoring Staff, 1978, EPA Grant No. A00905570.

Table I. Average $\dot{V}max$ in children in relation to daily outdoor O_3 and TSP.
(Adjusted for other outdoor variable)

	TSP ($\mu g/m^3$)*			
O_3 (ppm)	< 56	56-76	77+	All
< .038	+.108	+.239	+.156	.069
.038 - .051	+.042	-.162	-.061	.024
.052 - .079	+.242	-.021	-.474	-.115
.08 - .12	-.088	-.196	-.804	-.310
All	.115	-.027	-.227	

ANOVA $p<.0001$
* Reduced sample size due to lack of TSP data for all days.